Anisotropy of Upper Critical Field near Tc and Magnetic Gap of Superconducting URu2Si2 Single Crystal.

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ANISOTROPY OF UPPER CRITICAL FIELD NEAR T_C AND MAGNETIC GAP OF SUPERCONDUCTING URu_2Si_2 SINGLE CRYSTAL.

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Studying thermal conductivity and STM spectra in the normal and magnetic phase of superconducting URu_2Si_2 single crystal, we found, that the magnetic gap, partially opened on the Fermi surface below Neel temperature T_N = 17.5 K, is strongly anisotropic: gapped states mainly correspond to tetragonal ab plane.

At present, strongly correlated superconducting electron systems, including HTSC and heavy fermion superconductors are intensively investigated. The main purpose of our work was to study anisotropy of the magnetic gap in the superconducting URu_2Si_2 single crystal at $T>T_c$ from temperature dependences of thermal conductivity and STM spectra to compare their character with symmetry properties of the upper critical field H_{c2} near T_c.

The measurements were performed on a single crystal about 1*1*5 mm^3, oriented along c-axis ... T_c=1.16K [1]. Temperature dependences of thermal conductivity, electrical resistivity and Seebeck coefficient of URu_2Si_2 single crystal along the c-axis are shown in Fig.1. Assuming that below T_N: $k= AT+ BT^3+ A_0\exp(-\Delta/T)$, the k values being determined by electron, phonon and magnon contributions respectively and neglecting the change in electron part k_e ($k_e < (1/10)k$, see insert on Fig.1), then extrapolating $k=AT+BT^3$ dependence from $T=T_N$ to T=0 and substracting these values from experimantal data, we may estimate magnetic gap along c-axis $\Delta \approx 54K$.

Fig.2 presents typical anisotropy of dynamical conductivity, dI/dV at T=2K. For tip direction along ab plane a strong anomaly in dI/dV near zero bias

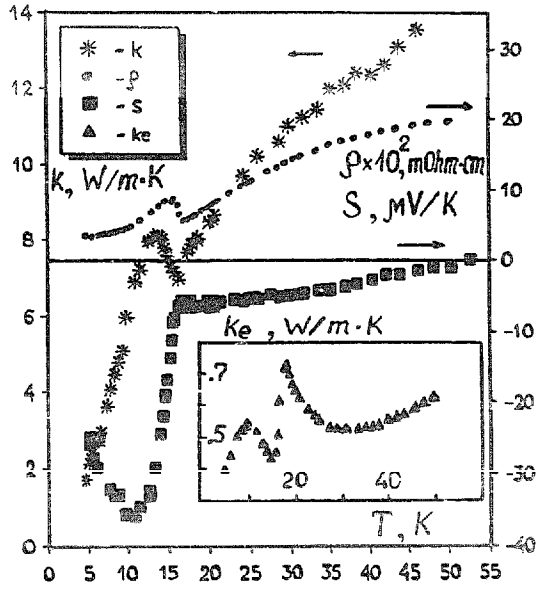

Fig.1 Temperature dependences of thermal conductivity, resistivity and Seebeck coefficient along c-axis for URu_2Si_2 single crystal. Insert shows the upper limit of electon part k_e .

voltage due to gap in the DOS is observed. Depending on tip position and separation between tip and surface, the value of the gap varies up to 20 meV. For tunneling spectra along tetragonal axis- only a small asymmetric feature near V=0 in the dI/dV curves was seen (Fig.2,insert).

In URu_2Si_2, below T_N spin waves with moment transfer and polarization vector along ordered moment[2] coexist with gapping of at least half of FS, obtained from heat capacity[3]. Discrepancy between gap value, estimated from heat transport along c-axis $\Delta \approx 54K$ and from heat capacity ($\Delta \sim 150K$) may originate from the strong anisotropy of magnetic gap. While for magnetic excitations along c-axis only a spin wave gap of 1.8 meV is formed[2], calculations of FS in ab plane show gapping of spectrum in A-directions and relatively high DOS in B-points[4] (see left insert on Fig.2). Our results are in a qualitative agreement with this FS picture: for c-axis only a relatively small feature in dI/dV characteristics near V=0 is seen, but along ab-plane strong anomalies in dI/dV, corresponding to gap at Fermi level up to 20 meV are observed.

Anisotropy of the $H_{c2}(T_c)$ studied at the same crystal[1], did not reveal 4-fold symmetry in the basal plane, possibly due to the small mean free path. Nevertheless, strong reduction of the H_{c2} in the c-direction in comparison with ab-plane[1], may also reflect symmetry of FS: for $\vec{H}$ II $\vec{c}$ electrons are rotating in the ab-plane and crossing regions of gapped DOS, while for $\vec{H}$ II ab-plane the probability of such intersections is much less.

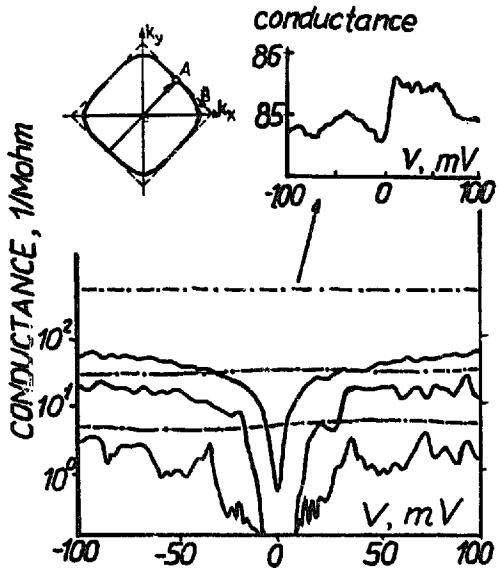

Fig.2 Dynamic conductivity dI/dV along ab-plane for various tip-sample distances (solid lines) and along c-axis (dashed-dotted lines) at T=2K. Left insert demonstrates calculated in[4] FS picture in the ab-plane.

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